HELDA
HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

UNIVERSITY OF HELSINKI

https://helda.helsinki.fi

Bridging the gap between ecosystem service indicators and ecosystem accounting in Finland

Lai, Tin-Yu

2018-06-10

Lai , T-Y , Salminen , J , Jäppinen , J-P , Koljonen , S , Mononen , L , Nieminen , E , Vihervaara , P & Oinonen , S 2018 , ' Bridging the gap between ecosystem service indicators and ecosystem accounting in Finland ' , Ecological Modelling , vol. 377 , pp. 51-65 . https://doi.org/10.1016/j.ecolmodel.2018.03.006

http://hdl.handle.net/10138/237779
https://doi.org/10.1016/j.ecolmodel.2018.03.006

cc_by_nc_nd
publishedVersion

Downloaded from Helda, University of Helsinki institutional repository.

This is an electronic reprint of the original article.

This reprint may differ from the original in pagination and typographic detail.

Please cite the original version.

Ecological Modelling 377 (2018) 51–65

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Bridging the gap between ecosystem service indicators and ecosystem accounting in Finland

Tin-Yu Lai[a,*], Jani Salminen[b], Jukka-Pekka Jäppinen[c], Saija Koljonen[d], Laura Mononen[c,e], Emmi Nieminen[f], Petteri Vihervaara[c], Soile Oinonen[f]

[a] University of Helsinki, Department of Economics and Management, P.O. Box 27, FI-00014, Helsinki, Finland
[b] Finnish Environment Institute (SYKE), Centre for Sustainable Consumption and Production, P.O. Box 140, Mechelininkatu 34a, FI-00251, Helsinki, Finland
[c] Finnish Environment Institute (SYKE), Biodiversity Centre, P.O. Box 140, Mechelininkatu 34a, FI-00251, Helsinki, Finland
[d] Finnish Environment Institute (SYKE), Freshwater Centre, Jyväskylä Office, Survontie 9 A, FI-40500, Jyväskylä, Finland
[e] University of Eastern Finland, Department of Geographical and Historical Studies, P.O.Box 111, FI-80101, Joensuu, Finland
[f] Finnish Environment Institute (SYKE), Marine Research Centre, P.O. Box 140, Mechelininkatu 34a, FI-00251, Helsinki, Finland

ARTICLE INFO

Keywords:
SEEA-EEA
Natural capital accounting
FEGS-CS
CICES
Aquatic ecosystem services
Marine ecosystem

ABSTRACT

In this paper, we examine how progress on ecosystem service indicators could contribute to ecosystem accounting within the scope of environmental-economic accounting in Finland. We propose an integration framework and examine the integration of ecosystem service indicators into environmental-economic accounting with two case studies relevant for Finland: (1) water-related ecosystem services and (2) the ecosystem services of fish provisioning in marine ecosystems. In light of these case studies, we evaluate the relevance of existing Finnish ecosystem service indicators, the data availability for ecosystem accounting in Finland, and the applicability of the System of Environmental-Economic Accounting ö Experimental Ecosystem Accounting (SEEA-EEA) framework to integrate Finnish ecosystem service indicators and other relevant data into environmental-economic accounts. The results indicate that the present ecosystem service indicators can assist in creating a basis for ecosystem accounting, but the indicators require further elaboration to be more compatible with the existing environmental-economic accounting system.

1. Introduction

In recent years, various disciplines have worked to improve the sustainability of coupled human-environment systems. One such contribution is literature in the field of accounting that acknowledges the insufficiency of the System of National Accounting (SNA) in measuring the negative environmental impacts of economic activities (Bartelmus et al., 1991; Boyd and Banzhaf, 2007; La Notte et al., 2017a; Repetto, 1992). Indicators such as gross domestic product (GDP) should be adjusted or supplemented with additional accounts to record the extent, development, and possible overconsumption of natural resources, and to consider negative environmental impacts such as pollution and detrimental use (see, e.g., Bartelmus, 2009; Nordhaus, 2006; Obst et al., 2016). To achieve this goal, two statistical frameworks have been developed to supplement the SNA: 1) the System of Environmental-Economic Accounting – Central Framework (SEEA-CF) and 2) the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA) (UN et al., 2014a,b). Both frameworks include accounting for biological natural resources, but the former system treats environmental assets individually, and the latter one applies a system approach (UN et al., 2014b). Fig. A1 (in Appendix A) presents the scope and differences between SEEA-CF and SEEA-EEA. In this paper, environmental-economic accounting refers to a broad concept that covers the scope of accounting under both SEEA-CF and SEEA-EEA. Ecosystem accounting, in turn, is defined here as the accounting for ecosystem assets and ecosystem services (ESs), as in Hein et al. (2015). Further, following Hein et al. (2015), we define natural capital as environmental assets that provide benefits to humans; ecosystem assets are thus considered as a type of natural capital.

On the European level, two major initiatives, the Mapping and Assessment of the Ecosystems and their Services (MAES) and the Knowledge Implementation Project on the Integrated system for Natural Capital and ecosystem services Accounting (KIP-INCA), play an integral role in developing ecosystem accounting. They attempt to implement the EU Biodiversity Strategy for 2020 by improving the visibility of ESs and by providing support for ES valuation and the integration of ESs into existing environmental-economic accounting and reporting systems (KIP-INCA Report, 2016; Maes et al., 2016). As part

* Corresponding author.
E-mail address: tin-yu.lai@helsinki.fi (T.-Y. Lai).

https://doi.org/10.1016/j.ecolmodel.2018.03.006
Received 31 March 2017; Received in revised form 21 February 2018; Accepted 13 March 2018
Available online 07 April 2018
0304-3800/ © 2018 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/BY-NC-ND/4.0/).

of the national MAES process, Finland has recently taken the first steps toward the identification and monitoring of the state and development of ESs and biodiversity by developing National Ecosystem Services Indicators (Finnish ES indicators) (www.biodiversity.fi/ecosystemservices/home; see Mononen et al., 2016). Environmental-economic accounting, however, has deeper roots in Finland (Autio et al., 2013; Hoffrén and Salomaa, 2014). Existing environmental-economic accounts include data on raw material consumption, energy supply and use, waste generation, greenhouse gas emissions, business activities of the environmental goods and services sector, and environmental protection expenditures (Statistics Finland, 2017a). Ecosystem assets and services, however, are not yet part of the Finnish environmental-economic accounting scheme operated by Statistics Finland. Therefore, this paper explores how Finnish ES indicators could be integrated into ecosystem accounting and how future work related to such integration could support the final goal of including ESs into Finnish environmental-economic accounts. For this purpose, two case studies following the approaches provided by SEEA-EEA are elaborated: ecosystem accounting for (1) water-related ESs, and (2) fish provisioning services from marine ecosystems. The latter case study can be regarded as a subset of water-related ESs but is presented separately for the sake of clarity and due to the different methodological approaches used.

The motivations for the choice of these particular case study topics were their high relevance to the economy and the fairly good availability of data related to them. Methodologically, SEEA-CF and SEEA-Water (UN, 2012) provide guidelines for asset (surface water and groundwater stocks), supply, and use accounts for water resources (UNEP et al., 2017). By contrast, SEEA-EEA is applicable to ecosystem accounting, which can consider comprehensive aquatic ecosystems and other water-related ESs in a systematic way. Earlier studies have applied SEEA-EEA to incorporate ES mapping and quantification data into ecosystem accounting from the regional to the continental scale (Khan et al., 2015; La Notte et al., 2017a; Office for National Statistic, 2016; Remme et al., 2014, 2015; Schröter et al., 2014; WAVES, 2017). According to Hein et al. (2015), no case studies existed at the time of publication that would have compiled an ES use account in practice. Later, La Notte et al. (2017a) provided data on actual ES flows of nitrogen retention used by two types of beneficiaries. However, the results from La Notte et al. (2017a) are too aggregated to be integrated into the SNA. In the WAVES project (2017), physical supply and use accounts for the ESs of carbon sequestration and storage water supply in Guatemala were compiled, but monetary use accounts were still missing. Khan et al. (2015) provided an outline of use accounts for freshwater ESs in the UK by identifying the beneficiaries, which can be regarded as the first step toward compiling ES use accounts. The first case study of the present paper aims to take one step forward by developing physical and monetary water ES use accounts compatible with the SNA.

Our second case study demonstrates the provisioning services of three commercially important fish species in the Baltic Sea: herring (*Clupea harengus membras*), sprat (*Sprattus sprattus*) and cod (*Gadus morhua)* (LUKE, 2017). Regarding fish provisioning services, some countries have already compiled asset accounts for fishery resources based on the well-developed SEEA-CF approach (ABS, 2012; Statistics South Africa, 2012; Anna, 2017). These accounts contain data on fish stock, fish catch, and economic activities within the fishery sector. However, understanding their links to whole marine ecosystems requires the application of ecosystem accounting and SEEA-EEA. The literature on marine ecosystem accounting is still scarce. Most of the existing papers focus on coastal ecosystems and emphasize experiments on compiling ecosystem extent and condition accounts (ABS, 2015; Eigenraam et al., 2016; Weber, 2014). Eigenraam et al. (2016) and ABS (2015) included fish provisioning services in their ecosystem accounting, but neither of them estimated the capacity for the ecosystem to provide this ES. In principle, ecosystem capacity connects an ecosystem asset with ESs, as it represents the ability of an ecosystem asset to generate a set of ESs in a sustainable way (UN et al., 2014b; UNEP et al., 2017). In practice, however, SEEA-EEA does not instruct how ecosystem capacity should be measured (UNEP et al., 2017), and the best way to define and measure ecosystem capacity has remained a somewhat controversial issue. In the case of terrestrial ecosystems, Hein et al. (2016) and La Notte et al. (2017a) use ecosystem capacity contradictorily. The former defines ecosystem capacity as a *flow* of an ES that is generated at sustainable level, and the latter defines ecosystem capacity as a *stock* that provides a sustainable ES. *Stock* quantifies the state of an ecosystem at one point in time, while *flow* always has a temporal dimension with several time points. This paper thus reviews both approaches to ecosystem capacity and proposes an operational measurement of this metric for marine fish provisioning services.

To sum up, ecosystem accounting is still at the experimental stage, and many concepts have not yet been operationalized. This study, with its two case studies, serves as a pilot for the evaluation of data availability and the potential ways to integrate Finnish ES indicators into national environmental-economic accounts. Methodologically, SEEA-EEA approaches and the outcomes from the Common International Classification of Ecosystem Services (CICES) and MAES processes are evaluated. This paper is organized as follows: Section 2 provides a general framework to integrate Finnish ES indicators and environmental-economic accounts through ecosystem accounting procedures, with a basic description of ecosystem accounting and the Finnish ES indicators. Section 3 presents the two case studies. Section 4 discusses how the Finnish ES indicators could be improved to facilitate ecosystem accounting and the implementation of the integration framework.

2. Material and methods

This section briefly reviews the Finnish ES indicators and the relevant SEEA-EEA accounts. Fig. 1 illustrates our schematic framework for the integration of Finnish ES indicators into environmental-economic accounts, and Table 1 lists definitions of ecosystem accounts that appear in Fig. 1. The Finnish ES indicators follow the CICES classification system and the so-called Cascade model (Mononen et al., 2016). The use of the Cascade model structured the resulting indicators into four different categories[1]: (1) structure, (2) function, (3) benefit and (4) value (Haines-Young and Potschin, 2010).

2.1. Use of structure and function indicators to develop ecosystem extent and condition accounts

Structure indicators (Fig. 1) define and measure the biophysical prerequisites for functioning ecosystems. Various land cover statistics have been used to link habitat type and ESs in Finnish ES indicators, especially the extent of these habitats across Finland (Mononen et al., 2016). When available, habitat condition data are included in the structure indicators (e.g., water quality or species assemblage) and function indicators (e.g., productivity of an area in a certain unit of time), although spatial ecosystem condition data are still rare. Geographical Information System (GIS) tools and spatial format data are commonly used but are not compulsory for ecosystem extent and condition accounts (Hein et al., 2015; UNEP et al., 2017). Thus, the structure and function indicators in Finnish ES indicators can provide direct input to the ecosystem extent and condition accounts. For some types of ESs, the natural resource stock information in existing environmental-economic accounts can act as an indicator for condition accounts (see the example of water stocks in Section 3.1.2).

[1] In the original Cascade model, there is a fifth category, “ESs”, between the function and benefit indicators.

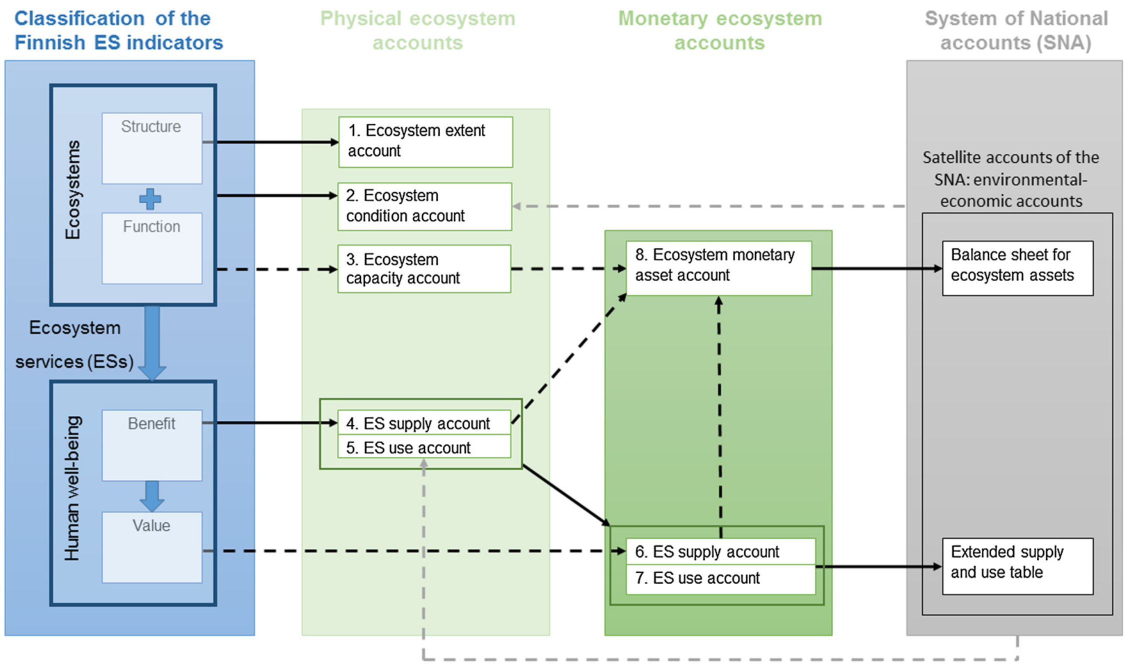

Fig. 1. Framework for integrating Finnish ES indicators into environmental-economic accounts.
The blue section contains Finnish ES indicators. Finnish ES indicators could be used to compiled ecosystem accounts (green section), which can be further classified into physical (light green) and monetary (dark green) accounts. Ecosystem accounts could be integrated into environmental-economic accounts. The black solid arrows mean that the data from previous stages can be directly used as input to the indicated accounts. The black dashed arrows mean that further calculation or processing procedures are required to compile the accounts. The gray dashed arrows show that current information in the SNA or environmental-economic accounts could be used for the compilation of ecosystem accounts (Note: The physical term in ecosystem accounts can also be integrated into environmental-economic accounts (UN et al., 2014a). However, the final aim of this integration is to make environmental information compatible with SNA data; thus, we only connect the monetary ecosystem accounts with SNA sections using solid black arrows) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

2.2. Use of structure and function indicators to develop ecosystem capacity accounts

Table 2 summarizes ecosystem capacity definitions from the recent literature. All these publications measured capacity based on a single ES, but only Hein et al. (2016) calls for sustainability assessment at the ecosystem level.

The definition of capacity from Hein et al. (2015) is based on the degradation of ecosystem conditions, which complicates its use. The approach from Hein et al. (2016) creates different possibilities for capacity, which may hamper the sustainability assessment of actual ES flows. La Notte et al. (2017a) followed Villamagna et al. (2013) to treat capacity as a stock but also provided a flow indicator (sustainable flow) that serves a similar function to “capacity” as used in the other literature summarized in Table 2. To determine whether capacity should be treated as a flow or stock, we clarify the relations between capacity and

Table 1
Ecosystem accounts.

Account type	Accounts	Definition
Accounts for ecosystem assets[a]	Ecosystem extent account (No. 1 in Fig. 1)	An account to show the area (size) of a given ecosystem.
	Ecosystem condition account (No. 2 in Fig. 1)	An account to present the quality of a given ecosystem in terms of various characteristics. Indicators of characteristics are chosen to reflect key ecosystem components and processes that influence the extent, state and functioning of ecosystems, such as nutrient level, species composition, productivity of the ecosystem, and hydrological cycles.
	Ecosystem monetary asset account[b] (No. 8 in Fig. 1)	The account records the value of an ecosystem asset.
Accounts for ecosystem capacity	Ecosystem capacity account (No. 3 in Fig. 1)	The ecosystem capacity reflects the ability of an ecosystem to provide ESs sustainably in the future. However, precise definitions of ecosystem capacity vary in the literature (see Table 2).
Accounts for ESs	ES supply account: ● Physical term (No. 4 in Fig. 1) ● Monetary term (No. 6 in Fig. 1)	The account records the actual ES flows supplied from ecosystem assets to humans. The account can show how an ES is provided by different ecosystems and/or how multiple ESs are provided by one ecosystem.
	ES use account: ● Physical term (No. 5 in Fig. 1) ● Monetary term (No. 7 in Fig. 1)	The account records the actual flows of ESs used by different economic sectors/beneficiaries.

Reference: Summarized from UN et al. (2014b), UNEP et al. (2017), Hein et al. (2015), and Hein et al. (2016).
[a] Definition of ecosystem assets: see Table A1 in the Appendix A.
[b] The name of this account is not consistent in documents. Ecosystem monetary asset account was used in UNEP et al. (2017). UN et al. (2014b) named the account an ecosystem asset account in monetary terms. In UN et al. (2014a), a similar account for natural capital was named as monetary asset account for a given type of natural resources.

Table 2
Comparison of different definitions of ecosystem capacity in selected recent literature.

Reference	Schröter et al. (2014)	Hein et al. (2015)	Hein et al. (2016)	La Notte et al. (2017a)
Definition of sustainability	Sustainability is not explicitly defined. In the examples given, the capacity flow of an ES is measured without considering the level of other ESs.	The sustainable ES flow is the maximum supply and use of an ES that does not lead to degradation in ecosystem condition.	The sustainable ES flow is the maximum ES supply and use that does not negatively affect the future supply of the same or other ESs from that ecosystem. The capacity indicator is measured for one ES, but sustainability needs to consider the ecosystem as a whole.	Ecosystem capacity is a stock that provides a sustainable flow of an ES. Sustainable flow is measured for a single ES.
Relation between capacity and actual ES use	Actual ES use can be lower or higher than the capacity.	Actual ES use can be lower or higher than the capacity.	When actual ES use is lower than the sustainable flow, capacity equals actual ES flow; when actual ES use is higher than the sustainable flow, capacity equals the sustainable flow.	Actual ES flow cannot be higher than the capacity, but it can be higher or lower than the sustainable flow.

ecosystem assets presented in the literature. In the case study from La Notte et al. (2017a), the physical term of the capacity was measured as the total area of constructed wetlands that was required. Therefore, it is unclear how these imaginary wetlands are linked to real ecosystem extent and how they reflect the ability of the existing ecosystem asset to provide sustainable flows. However, the flow concept of capacity in other publications (Hein et al., 2015, 2016; Schröter et al., 2014) is clearly represented as the sustainable level of an ES flow provided by an existing ecosystem.

In this paper, we follow Hein et al. (2016) and Hein et al. (2015) and define ecosystem capacity as a flow that is the sustainable level of an ES generated by a given ecosystem asset, under current ecosystem management and ES use; and the sustainable level is the maximum level of ES used that does not negatively affect the future supply of that or other ESs. Thus, when the actual ES use is above the ecosystem capacity, ES use that results in ecosystem degradation and decreases the capacity in the next accounting period is not sustainable (Hein et al., 2016). The capacity is subject to changes in the management system and in other factors affecting ecosystem condition (Hein et al., 2015, 2016; La Notte et al., 2017a; Schröter et al., 2014).

In Finnish ES indicators, function indicators (Fig. 1) define the ability of an ecosystem to produce ESs within a certain timeframe. This delivery of ESs, representing the total ESs that are generated from an ecosystem, follows the supply definition of ESs from Burkhard et al. (2012): "*Supply of ESs refers to the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given time period*". The capacity and definition in Burkhard et al. (2012) neither indicates whether the ESs are used nor whether the potential use has been sustainable. Therefore, the application of such function indicators in ecosystem accounting requires an estimate for the sustainable level of ES use in the given timeframe. In addition, a change in ecosystem extent influences the level of function indicators, and thus ecosystem extent should also be considered when estimating ecosystem capacity.

Since sustainability levels are not available in Finnish ES indicators at this moment, we explore the potential candidates of capacity indicators from fishery sciences. Although sustainable catch was defined as the capacity for fish provisioning in UN et al. (2014b), and UN et al. (2014a) demonstrated an example of the sustainable yield of fish resources for a simple single species case, the definition of sustainable catch is still manifold in fisheries management literature. Piet et al. (2017) tested several single-species-based sustainable indicators, including surplus production, single-species maximum sustainable yield (MSY), and reproductive capacity, to be used as capacity indicators for fish provisioning services. However, we decided to use multispecies MSY, which considers food web interactions, as an input for our capacity account for three reasons: (1) Research has found evidence for interactions among herring, sprat, and cod in the Baltic Sea, and multispecies biological reference points for sustainable harvest have been advised for fishery management objectives (Collie and Gislason, 2001; Gislason, 1999; ICES, 2013; Walters et al., 2005). (2) In national accounts, the account structure is divided by sectors (e.g., fishery sector or aquaculture sector) but not by species (Statistics Finland, 2017b). (3) The latest KIP-INCA report (La Notte et al., 2017b) mentioned that the final process for accounting fish provisioning services should consider food web interactions, although the report currently follows the surplus production method from Piet et al. (2017) for single species.

2.3. Use of benefit indicators to develop physical ES supply accounts

Benefit indicators (Fig. 1) express the used share of total ESs generated from an ecosystem (Mononen et al., 2016); e.g., the share of wild berry yields that have been harvested by people or the volume of groundwater extracted for human purposes. This indicator has the same meaning as the actual ES flows in ecosystem accounting (Schröter et al., 2014). Thus, benefit indicators can be used to compile physical ES supply accounts.

2.4. Development of the physical ES use account

The current Finnish ES indicators can contribute little to a physical ES use account. Compiling ES use accounts requires detailed data about the users of ESs, but Finnish ES indicators lack such data. ES user data relies on the collection of social-economic statistics; existing information about sectors in the SNA could also help in understanding the sectors' use of some ESs (UNEP et al., 2017). Even though the data sources for supply and use accounts may be different, compiling ES supply and use accounts should occur at the same time and in an iterative fashion so that the data for both accounts can be complemented or fine-tuned to balance the two accounts according to the principles of SNA (UNEP et al., 2017). This balance between supply and use accounts means that the total domestic supply of an ES is either used by domestic beneficiaries or exported to the rest of the world (Hein et al., 2016; UNEP et al., 2017).

2.5. Use of value indicators to develop monetary ES supply accounts

The value indicators (Fig. 1) in Finnish ES indicators are divided into four categories: 1) economic, 2) social, 3) health, and 4) intrinsic values; this approach was modified from the UK National Ecosystem Assessment (2011). Economic value reflects the economic statistics of monitored or observed values. Social value relates to metrics such as the number of jobs. The data for economic and social values are usually estimated or collected from other socio-economic statistics. Health value is poorly developed, but it has been noted that the degradation of some ESs will lead to negative impacts on human health and thus to increased societal costs (e.g., Lampi et al., 1992). Intrinsic value is mainly qualitative and especially reflects cultural values, such as national identity and historical relevance, and it can be attributed to every living system. Within these four types of value, social value does not need to be incorporated into ecosystem accounting since SNA data already include social value among labor inputs (EU et al., 2009). Among the remaining value types, economic value, representing a middle transaction step in a value chain from nature to humans, is the only value type that meets the valuation standard for accounting.

Depending on the ES type, the procedures required to apply economic value indicators to supply accounts are different. In the Finnish ES indicators, the economic indicators of provisioning services and some cultural services (like recreational services) that have market prices are estimated by producer income. In this case, the monetary value of an ES supply is measured as a resource rent, which is derived by deducting the operational costs from the producer income and then adjusting the result with taxes or subsidies (UN et al., 2014a, 2014b; Remme et al., 2015). The operational costs include intermediate costs, labor costs, and user costs of fixed capital, which are all itemized in the SNA data (EU et al., 2009). Most regulation services and some cultural services do not have markets. In Finnish ES indicators, some such ESs are valued by methods compatible with SEEA-EEA, e.g., the avoided cost approach for water retention or erosion control (UN et al., 2014b). In such cases, the economic value from Finnish ES indicators can be used directly in the compilation of monetary ES supply accounts. In all cases, the monetary and physical ES supply accounts need to correspond to each other in a given year.

2.6. Development of the monetary ES use account

The monetary ES use account is compiled based on: (1) sectors' use from the physical ES use accounts, and (2) the unit value of ESs from monetary ES supply accounts. As in the physical account, monetary use and supply need to follow the balance rule. In addition, like ESs supply, the monetary and physical terms of the ES use account need to correspond.

2.7. Development of the monetary ecosystem asset account

Compiling the monetary ecosystem asset account requires three steps:

2.7.1. Step 1: estimate the physical term of expected ES flows

Estimating the patterns of ESs that an ecosystem asset can provide in the future, the so-called physical terms of expected ES flows (UN et al., 2014b), is challenging due to the complex dynamic and non-linear changes in ecosystems (Hein et al., 2016). Such an estimation requires information about the possible ES demand in the future, which could be based on but may not necessarily equal current actual ES flows. As the sustainability of both current ESs and possible future ES demand influences the pattern of future ESs, an ecosystem capacity account is also needed to estimate the expected ES flows (Fig. 1) (UN et al., 2014b; Hein et al., 2016). In our marine fish provisioning case, we used a multispecies bio-economic model from Nieminen et al. (2016) and Nieminen et al. (2012) to estimate physical expected ES flows. The model not only follows the multispecies assumption from the capacity account but also has the ability to consider ecosystem condition factors, such as salinity, to increase the accuracy of stock estimations. The applied model is an age-structured model, describing the food web interactions of cod, herring and sprat, the economics of the fishery sector, and the impacts of fishing on the stocks of the three fish species.

2.7.2. Step 2: estimate the monetary term of expected ES flows

This estimation requires the results of physical expected ES flows and the monetary value of the ES supply account. The unit value of ESs calculated from the ES supply account has to also incorporate the inflation rate before being multiplied with the physical expected ES flows (UN et al., 2014a).

2.7.3. Step 3: estimate the monetary value of an ecosystem asset by discounting the monetary value of expected ES flows

Each ecosystem asset is valued as the net present value (NPV) of the expected ES flows of multiple ESs that the ecosystem can provide. Multiple ESs are required to estimate the value of an ecosystem asset comprehensively. The length of expected ES flows that an ecosystem asset can provide is called asset life. If the current and expected use of the ES is sustainable, asset life can be forever. In the accounting sense, however, a maximum asset life (e.g., 25 or 30 years) is determined to value ecosystem assets since the NPV usually becomes very low after this period (UN et al., 2014b; UNEP et al., 2017).

The results of ecosystem accounts can be further integrated into existing environmental-economic accounts in many different ways (UN et al., 2014a, 2014b). Fig. 1 shows two examples of integrating monetary ecosystem accounts.

The current Finnish ES indicators provide an overview of the key ESs, although there is a lack of detailed data in many of the indicators. The collection of spatial data for mapping structure and function indicators is progressing via the on-going MAES process. At the same time, there is an ongoing demand for the development of benefit and value indicators. In the case studies (Section 3), some of the lacking data are supplemented by alternative data sources to make the ecosystem account testing in this paper as comprehensive as possible.

3. Case studies

In this section, we present two examples, water-related ESs and fish provisioning in marine ecosystems, to implement the integration framework proposed in Section 2. In both cases, we begin with an overview of the whole ecosystem. However, when compiling ES supply and use accounts and estimating the expected ES flows, we focus only on the selected ESs in order to test the implementation of the integration framework.

Fig. 2. A schematic approach to different uses of water in its various forms and to the services provided by (A) aquatic ecosystems, (B) the atmosphere, and (C) terrestrial ecosystems. The numbered items in the figure refer to the ecosystem functions (A1) surface water and ice; (B1) rain water; (B2) snow; (C1) groundwater; (C2) soil water; (C3) frost; and to their beneficiaries (1–7), with corresponding sectors (NACE codes) indicated in brackets. (1) Precipitation-utilizing sectors: agriculture [01], forestry [02] and nature conservation areas [93], and gathering of wild-growing non-wood products [023]; (2) in-stream uses of water in animal husbandry [014] and hunting [017]; (3) fishing and aquaculture [03]; (4) hydro-electric power generation [351]; (5) water traffic [50]; (6) letting and operation of estates [682], accommodation [55], and food and beverage service activities [56]; (7) cultural and sports activities [90–91; 93]; (8) water flows (abstraction) from the environment to the economy; and (9) water flows from the economy to the environment, including subsequent natural attenuation of emissions in surface water bodies.

Table 3
Data and data sources for open water asset accounts (ecosystem extent and condition accounts)[a].

	Indicators (unit)	Value	Reference
Ecosystem extent	Surface water area (km^2)	34 536	National Land Survey (2017) and Finnish ES indicators
Ecosystem condition	Water volume (km^3)	235	Kettunen et al. (2008), rivers are not included
	Proportion of lakes in good chemical status (%)	85	SYKE (2017) and Finnish ES indicators
	Proportion of rivers in good chemical status (%)	64–65	
	Proportion of species in favorable status in boreal region (%)	63	Finnish ES indicators and Biodiversity.fi (2014)
	Proportion of species in favorable status in alpine region (%)	83	

[a] Ecosystem asset accounts are commonly presented in a format that switches the columns and rows (UNEP et al., 2017; Khan et al., 2015). Since our study provides the account data for one year with data sources, we chose this format for easier reading. The same reasoning is applied in Tables 4 and 6.

3.1. Ecosystem accounts for water-related ESs

In this case study, we propose how services provided by aquatic ecosystems and the different uses of water in its various forms and from different sources could be incorporated into ecosystem accounting. The focus is on open water ecosystems; wetlands, atmospheric water and water in terrestrial ecosystems are not analyzed in detail. We start by defining the system boundaries of our analysis and then continue by testing the compilation of physical ecosystem asset accounts, as well as ES supply and use accounts, by following the integration framework (Fig. 1) and SEEA-EEA. Accounts for capacity, expected ES flows and ecosystem monetary assets are not tested in this case study. Asset accounts comprising ecosystem extent and condition accounts for open water ecosystems build mainly on previous work conducted with the Finnish ES indicators. ES supply and use accounts are tested for water abstraction. For other types of water-related provisioning, regulating, and cultural services, we outline potential formats and data sources for their supply and use accounts. Fig. 2 describes the ecosystems, functions, and services of water-related ESs.

3.1.1. System boundaries

Water is present in all three major compartments of the planet: aquatic and terrestrial ecosystems and the atmosphere. They all provide water-related services that should be acknowledged in accounts. Rainfall, including snowfall, is part of the hydrological cycle, which UNEP et al. (2017) recommends considering in ecosystem accounting. Soil and groundwater are elements of terrestrial ecosystems. Freshwater ecosystems include open waters (e.g., river ecosystems and lake ecosystems) and wetlands (Khan et al., 2015). Wetlands include swamps, mires and peatlands, shallow lakes, and riparian zones, which together make up to 25% of the total land area of Finland (Biodiversity.fi, 2014; Wijesingha, 2016). This case study, however, focuses on open freshwaters and on freshwater itself in various ecosystems, as illustrated in Fig. 2.

3.1.2. Ecosystem extent and condition accounts

3.1.2.1. Inland waters. The extent of the open water ecosystems in Finland is summarized in Table 3. The total area of inland water bodies is 11.4% of the total land area of the country. The Finnish National Land Survey updates data on the total area of inland water bodies annually.

In ecosystem accounting, the stock of water resources is treated as a characteristic indicator in the ecosystem condition account (Khan et al., 2015; UNEP et al., 2017). The total volume of the inland water bodies in Table 3 is calculated by multiplying the total surface water area by the average depth of approximately 7 m for Finnish inland lakes (Kettunen et al., 2008). Finnish ES indicators have several species-related indicators for inland waters, including threatened inland water

Table 4
Data for ecosystem extent and condition accounts for aquifers classified as important or potentially applicable to water supply.

	Indicator (unit)	Value	Reference
Ecosystem extent	Aquifer area (km^2)	9 845	Britschgi et al. (2009)
Ecosystem condition	Annual water productivity (km^3/year)	1.56	
	Proportion of aquifers with good chemical status (%)	91	SYKE (2016)

species and the conservation status of species identified in the EU Habitats Directive. In Table 3, the proportions of inland water species with favorable status in two climatic regions (boreal and alpine) are given together with data on inland surface water quality.

3.1.2.2. Groundwater. Finland has 6,020 classified aquifers, approximately 3,800 of which are classified as important or potentially applicable for water supply purposes (SYKE, 2016). Next to these aquifers, groundwater is present practically everywhere in the subsurface and the bedrock, but its volume and chemical status are difficult to assess. In general, groundwater quality and productivity vary greatly outside the classified aquifers. An asset account for groundwater is presented in Table 4, following a similar structure to that for inland open waters. In this case, however, the ecosystem extent represents the aquifer area classified as important for or applicable to water supply rather than the overall total classified aquifers[2] or a specific ecosystem type. Condition indicators are also presented for the same range of data.

The ecosystem condition indicators reflect the connections between groundwater quality and terrestrial ecosystems, including the human activities and management practices affecting them. Groundwater quality is adversely affected primarily by chemical or microbiological contamination caused by contaminated sites of various kinds and origin (e.g., agriculture, industry, and small-scale businesses) (Molarius and Poussa, 2001; SYKE, 2016) and on-going activities such as road deicing.

3.1.3. Supply and use accounts

3.1.3.1. Abstracted water. In Finland, surface water uptake (2.0 km^3, including artificial recharge) accounted for approximately 1.4% of the total surface water stock in 2010, and groundwater uptake (0.2 km^3) from aquifers classified valuable for water supply was approximately 10% of their annual groundwater productivity (Salminen et al., 2017). Surface water and groundwater are also used for cooling: of the total 8.1 km^3 used for this purpose, 20% (1.8 km^3) is fresh surface water; the shares of groundwater and brackish water are < 0.1% and 80%, respectively (Salminen et al., 2017). Even though the rates of abstraction are well below the rate of formation of groundwater and the stock of surface water, evaluating whether the rates are locally safe or sustainable requires additional analysis on their local long-term effects (Kløve et al., 2011).

A summary of the flow volumes from the environment to the economy sectors (ES use accounts) is presented in Table A2 (in Appendix A), which shows that 20 sectors out of the 26 abstract water from the environment. The total groundwater use (0.3 km^3) in Table A2 is higher than the groundwater uptake mentioned above. The reason is that the groundwater abstraction volume in Table A2 includes groundwater uptake outside the aquifers classified valuable for water supply. Of the abstracted fresh surface water and groundwater, approximately 0.4 km^3 is used by the water supply sector (NACE[3] 36) to produce mains water. Table A2 also shows the aggregate mains water volumes delivered within the 26 economy sectors in Finland in 2010.

We use the volume of water abstracted by the water supply sector to estimate the resource rent, as mains water reflects market pricing. Based on the input-output data from Finnish national statistics (Statistics Finland, 2017c), the total production of the water supply sector is 588 million EUR. Based on the valuation approach described in Section 2.5, the operational surplus, 75 million EUR in the input-output data, can be regarded as resource rent for the ESs used (403,472,465 m^3) by the water supply sector. The unit resource rent of ESs, thus, is 0.186 EUR for 1 m^3 of abstracted water. The resource rent that each sector should pay for its water abstraction from groundwater and surface water can be seen in Table A2.

3.1.3.2. Return flows from the economy to the environment. Water flows from the economy to the environment generally consist of abstracted water that is returned after use. The physical and chemical composition, however, changes during the use phase depending on the purpose for which it has been used. For cooling water, thermal load is generally the most relevant impact. For other waters, e.g., at a wastewater treatment plant, the removal or recovery of various (aqueous) substances, such as nutrients, organic compounds, and particles is required prior to introduction back to the water body. In many cases, the abstracted water is returned to another water body rather than its original water source. For instance, abstracted groundwater is returned to a surface water body, and abstracted freshwaters are introduced into the sea. Even though nutrient removal rates have significantly improved over the years in Finland (Säylä and Vilpas, 2012), the natural biological and physicochemical processes in the receiving bodies (or said regulating services), are still needed to buffer the impacts of the remaining substances. In addition to the returned water flows described above, various substances are also washed out from land areas to groundwater and surface water bodies by precipitated water. In the receiving water bodies, various physical, chemical, and microbial attenuating processes remove aqueous substances and reduce their concentrations.

The emission accounts (Tattari et al., 2015) for phosphorus (P) and nitrogen (N) also provide data for P loading from airborne deposits and natural leaching to inland water, which is useful for the estimation of relations among human activities, P cycling, and water quality. The data provided by Tattari et al. (2015) were recently improved in Salminen et al. (2017), but they remain rather general, with only 16 aggregated sectors. For substances other than N and P, emission accounts are still missing. How much and how effectively water bodies can dilute, remove or immobilize various emissions and how these emissions affect them and the ESs they provide remain open questions.

3.1.3.3. ESs from in situ water and rainfall. While recent improvements in water accounting for abstracted water and emissions to water in Finland provide a solid basis for the careful assessment of water flow accounts (from the environment to the economy, within the economy, and from the economy to the environment), many more data-related challenges are encountered in other forms of water use. From an accounting perspective, however, it is evident that a vast majority of economic sectors depend solely on abstracted water. Subsequently, the number of individual sectors which use other provisioning, regulating, and cultural services is quite limited (Table 5). The sectors of the Finnish economy for which atmospheric water (rainfall) and in situ use (passive use) of open waters are relevant are summarized in Table 5.

First, crop growth mainly depends on precipitation, as only 3% of the fields in Finland are equipped with irrigation facilities (Tike, 2013), and not all of these fields are irrigated each year, depending on the weather conditions during the growing season. For instance, in 2010, 19% of the 68,600 ha with irrigation facilities was indeed irrigated (Tike, 2013). Occasional irrigation is limited to open-air cultivation of vegetables, berries and fruits, and potatoes; the remaining crops, including cereals, are watered with rain. Similarly, forests (i.e., forestry)

[2] Finnish ES indicators include the extent and water productivity for total classified aquifers. However, to keep the data range consistent throughout the account, we chose an alternative data source.

[3] NACE is "statistical classification of economic activities in the European Community", which classify the industries in different sectors (EUROSTAT, 2008).

Table 5
Outline of industries that depend directly on rainfall or snowfall (ATM; refers to atmospheric ecosystem) or use in-stream provisioning (PROV) and/or cultural (CULT) services provided by water-related ecosystems. The value of each sector's output in 2010 is indicated together with industry-specific examples of the relevant uses and data sources for the water-related ESs.

NACE	Industry	Output	ATM	IN-STREAM		Example
code		Million EUR[a]		PROV	CULT	
011-012	Growing of crops	1 550	x			> 97 % of cultivated area produces rain-fed crops (Tike, 2013).
014	Animal husbandry excl. reindeer husbandry	2 342	x	x		Grazing livestock (incl. reindeer) use surface waters for drinking.
017	Hunting, trapping and related service activities	83	x			Wild animals drink surface water and snow.
021	Silviculture and other forestry activities	1 770	x			Trees growing in managed forests are exclusively rain-fed (Launiainen et al., 2014).
023	Gathering of wild-growing non-wood products	75	x			Wild berries, mushrooms and plants are exclusively rain-fed.
031	Fishing	120		x	x	Professional and sports fishing; see Section 3.2.
032	Aquaculture	56		x		In-stream fish farming covers > 50 % of all (n = 144) inland facilities.
35111	Production of electricity with hydropower	1 200		x		The share of hydropower is 10-20 % (Statistics Finland, 2016).
37	Sewage	540		x		Natural attenuation of emissions in the receiving water bodies.
50	Water transport	2 300		x		
55	Accommodation	1 565			x	Camping areas, rental holiday cottages are often located by water.
682	Letting and operation of real estates	23 275			x	80% of the 550 000 summer cottages stand by watersheds (Nieminen, 2009). Water quality of the water body significantly affects the land price (Artell, 2013).
91	Cultural activities	1 449	x	x	x	Visitors in national parks (Metsähallitus, 2017).
93	Sports and leisure activities	2 106	x	x	x	Number of public swimming beaches (Zacheus, 2008); Popularity of various water-, snow- and ice-exploiting outdoor sports (SLU, 2010).

[a] Reference: Statistics Finland (2017b).

in Finland depend fully on rainwater, as do natural products such as berries, mushrooms, and other wild-growing non-wood products. Water in the form of snow is also essential for many skiing centers and other winter sports activities. Other relevant sectors for provisioning services are fishing, aquaculture, the production of electricity with hydropower, and water transport. For these industries, the economic value they produce is indicated in Table 5 together with examples of the various types of ESs these sectors use.

3.2. Ecosystem accounts for marine ecosystems and fish provisioning services

In this section, we present an example compilation of a full set of accounts for marine fish provisioning for herring, sprat, and cod. For this case, we compile the accounts for 2012. Herring and sprat constituted over 90% of the Finnish marine landings in 2012 (LUKE, 2017). Cod was selected as an example for measuring sustainable use and for testing the capacity account compilation, as cod has been overfished and its populations are still low (ICES, 2013, 2015a).

3.2.1. Ecosystem asset accounts

The ecosystem extent of marine ecosystems for a country is defined as the country's exclusive economic zone (EEZ) (UN et al., 2014b). The EEZ helps to identify local marine resources that should be included in national ecosystem accounts, but the species we focus on migrates across the Baltic Sea. Therefore, we first dealt with fish provisioning services from the perspective of the whole Baltic Sea, and then considered the Finnish share of the catch to integrate the ES data into Finnish accounts.

For fish provisioning services and for fish stock formation in particular, water temperature, oxygen and salinity are important factors (e.g., Koster et al., 2005 and Ottersen et al., 2006), and the fish stock level further determines the capacity to provide fish. Thus, such factors are advised to be included in ecosystem accounts (UN et al., 2014b). However, Finnish ES indicators only provide information on the overall status of coastal waters and the concentrations of N and P. Table 6 shows the asset accounts of Finnish marine ecosystems, which include the ecosystem extent and condition indicators from Finnish ES indicators.

Unlike in accounting for water, current SEEA-EEA and related documents (UN et al., 2014b; UNEP et al., 2017) do not clarify how to link the SEEA-CF asset account of fish stock to ecosystem accounting. Recall that, in the water example, water stock serves as a condition indicator in ecosystem accounting. In addition, species-related indicators (e.g., species richness) are considered as ecosystem condition indicators (UN et al., 2014b). Therefore, we also present the spawning stock biomass (SSB) of the fish stocks in the ecosystem condition account. The Finnish ES indicators use SSB data from the International Council for the Exploration of the Sea (ICES) as a function indicator, so we also used ICES as one of our data sources. The Finnish share of the SSB is estimated based on the SSBs of the three species in the Baltic Sea and the Finnish catch share (see Table A3 in Appendix A).

3.2.2. ES supply and use accounts

The Finnish ES indicators define fish catch as a benefit indicator. Thus, we also use fish catch data to populate the ES use and supply accounts (Table 7). The total supply of fish should include commercial fisheries, together with recreational and household catch (UN et al., 2014b). Without further division of data between recreational and household catch, we place commercial and recreational catch into the ES supply and use accounts. Recreational fish catch should be allocated to the recreational sector (NACE 93), and all commercial catch should be considered as the ES use from fishery sectors (NACE 031), based on EUROSTAT (2008). Unlike abstracted water, which can be acquired from different ecosystems, all marine fish catch is provided by marine ecosystems.

The landing value of these three species totaled 26.6 million EUR in 2012 (LUKE, 2015). Based on the input-output data from Finnish national statistics (Statistics Finland, 2017c), an operating surplus without a net mixed income in the fishery sector accounted for 13.5% of the total income of the whole fishery sector in 2012. The operating surplus was calculated by subtracting all operational costs from the total production value in the fishery sector; this calculation considered the effects of taxes, subsidies, and mixed income. Without further information about the cost structure, we use this operating surplus percentage of the total production value (13.5%) as a proxy for the resource rent

Table 6
Asset accounts of Finnish marine ecosystems in 2012.

		Indicator		Units of measure	Value	Reference
Ecosystem extent		Area of EEZ cover		km^2	81 000	Claus et al. (2016)
Ecosystem condition	Water quality	Overall status of coastal water		% of coastal water area with good and high quality	25 (2013)[a]	Finnish ES indicators
		Nitrogen concentration in surface water		μmol/l (Gulf of Finland/Gulf of Bothnia/ Archipelago Sea)	190/133/203	Biodiversity.fi (2014)
		Phosphorus concentration in surface water			31.3/6.2/31.0	
	Finnish share of fish stock	SSB	Herring	thousand tons	863–1165	See Table A3 in Appendix A
			Sprat		33	
			Cod		4	

[a] Data not available for 2012.

Table 7
ES supply and use account for marine fish (herring, sprat, and cod) provisioning services for 2012.

NACE	031	93
Sectors that use fish provisioning ES	**Fishing (herring/ sprat/cod)**	**Sports and leisure activities (herring/ sprat/cod)**
Actual supply of fish provided from marine ecosystem	128 (thousand tons) (117/8.96/ 1.67)[a]	735 (tons) (720/13/3)[b]
Monetary value of the ES	3.6 (million EUR)	Value as recreational services

[a] ICES (2015a), total Finnish commercial catch including other species is 133 thousand tons (LUKE, 2016).
[b] LUKE (2014), total Finnish recreational catch including other species is 5.9 thousand tons.

Table 8
An example estimation of indicators for a capacity account.

Unit: thousand tons	Herring	Sprat	Cod
Multispecies MSY[a]	178	225	77
MSY for the populations that were not included in multispecies MSY	106[b]	–	20[b]
Total MSY in Baltic Sea	284	225	97
Finnish MSY	161	8.91	2.3

[a] ICES, 2013, including stocks of herring in SD 25–29 and 32, sprat in SD 22-32, and cod in SD 25-32.
[b] ICES (2012), including herring in SD 30–31 and cod in SD 22-24. For cod, the total allowable catch in 2012 is used as a replacement due to a lack of estimated MSY.

percentage of the landing value (26.6 million EUR). Thus, the resource rent of the three species in 2012 was approximately 3.6 million EUR (Table 7), and the unit resource rent was 28 EUR per ton. Recreational fishing is commonly identified as a cultural service (Ahtiainen and Öhman, 2013; Magnussen and Kettunen, 2013; Pope et al., 2016), and thus the approach for valuing recreational services should be used for recreational catch (UN et al., 2014b).

3.2.3. Ecosystem capacity accounts

To use multispecies MSY as a capacity indicator, we multiplied the total multispecies MSY estimated by ICES (2013) with the Finnish catch share (Table 8). By comparing the Finnish multispecies MSY with actual ES use (Table 7), the results show that the sprat harvest slightly exceeded the sustainable level, while herring and cod were harvested sustainably.

3.2.4. The expected ES flows and ecosystem monetary asset account

To demonstrate the estimation of physical expected ES flows with updated parameters, we apply the model from Nieminen et al. (2016) and Nieminen et al. (2012). Salinity, often used as an ecosystem condition parameter, affects cod stock development (Nieminen et al., 2012). As no salinity information is available in the current ecosystem condition account, we chose the current salinity level as “bad condition” for cod recruitment based on ICES (2015a). In addition, the average values for 2011–2013 were used for the biological parameters in the model (Nieminen et al., 2016), corresponding to the accounting year (2012) of our case study. For the expected ES demand, we assumed that the future demand of this ES remains similar to the demand in the accounting year. Hence, for human-related parameters, such as prices and fishing mortality, the average values for 2011–2013 were chosen. Since the model was designed to simulate the fish stock of the whole Baltic Sea, the updated price was determined as the average for the countries surrounding the Baltic Sea by using data from the EU (2015). The updated fishing mortality data were from ICES (2015a). As in other accounts, the Finnish catch share was used to calculate the physical expected ES flows for Finland (Table A4). The expected ES flows of cod follow a decreasing trend until the end of asset life. This implies that the determined fishing mortality of cod is higher than the fishing mortality for cod harvested at capacity level in the model, which means that expected ES flows are higher than the capacity. By contrast, the expected harvests estimated for herring and sprat are anticipated to increase in the later years of the asset life, so the expected ES flows for these two species are anticipated to be within the capacity.

Next, we use the resource rent of current ES use, 28 EUR per tons of fish, to estimate the resource rent of expected ES flows. The inflation rate in 2012–2013 was 2.2% (Eurostat, 2017), and thus we assumed that the unit resource rent will increase by 2.2% every year. By multiplying the total physical expected ES by the unit resource rent, we get the value of expected ES flows (Table A4). Further, by discounting the value of expected ES flows by a 2% discount rate,[4] the estimated NPV of the expected ES flows totals 90 million EUR. The sum can also be regarded as a partial value of Finnish marine ecosystems. The total value of Finnish marine ecosystems can be estimated only when all current use types of ESs are considered.

4. Discussion

The two case studies provide evidence that Finnish ES indicators can contribute to ecosystem accounting, particularly in regard to ecosystem extent and condition accounts (asset accounts). Data in Finnish ES indicators, however, are not updated regularly, a limitation already identified during the indicator development process (Mononen et al., 2016). Therefore, a single-year compilation of accounts cannot be used to evaluate sustainability issues and potential environmental degradation. Such degradation can only be revealed when the ecosystem condition or capacity decreases (UNEP et al., 2017), and observing such a

[4] This discount rate was determined to be same as the discount rate used in the model for estimating the physical expected ES flows.

change requires data from more than one year. To serve as a source of input data for ecosystem accounting, Finnish ES indicators should be collected and updated on a regular basis.

In this paper, some of the ecosystem condition indicators were selected based on their data format and the completeness of the database. Ideally, ecosystem condition indicators should reflect the services in question. For example, salinity plays a key role in determining the capacity of marine ecosystems to provide fish. However, a salinity indicator is currently missing from the Finnish ES indicator database, and therefore cannot be used to populate the condition account for the marine fish provisioning service. Because the contents of Finnish ES indicators are not updated regularly and do not provide all relevant data, this paper uses alternative sources to populate the ecosystem accounts. However, in the case of water-related ESs, the data used were not strictly from one particular year. This results in some methodological inconsistency and minor inaccuracy when the data are combined with economic data representing one particular year. Groundwater productivity (Table 4), for instance, is based on the average infiltration rate over several years rather than that for one year. In spite of this, the case study still demonstrates the principles of how ecosystem account compilation for water-related ESs could be accomplished.

In present Finnish ES indicators, undetermined thresholds of sustainability levels for ES provisioning create a challenge in compiling capacity accounts. Due to this challenge, the physical expected ES flows and monetary ecosystem asset accounts could not be compiled for the two case studies by using Finnish ES indicators. Developing approaches and models to overcome these shortcomings and challenges is paramount for using the indicators in accounting, and even more importantly, for using accounting in sustainability assessments. In the marine fish provisioning case, we first used multispecies MSY as the sustainability indicator, and then used a multispecies bio-economic model to estimate the expected ES flows. In our application, the capacity that was used for estimating expected ES flows was determined by the model, rather than using the value from capacity accounts. However, the results in Section 3.2.3 and Section 3.2.4 do not conflict: one identified the sustainability of current ES use, but the other showed the sustainability of potential future ES use. We recommend that these two stages be reconciled in future accounting systems. Nevertheless, this example still provides a starting point for future work in both developing the sustainability indicators and capacity accounts, and estimating the expected ecosystem service flows.

In summary, the present Finnish ES indicators could be used in their current form to compile ecosystem extent, condition, and ES supply accounts for some ESs (e.g., the supply of fish provisioning is available in Finnish ES indicators). Furthermore, Finnish ES indicators have the potential to be used in the development of capacity accounts. If the sustainability levels for function indicators can be estimated, the effects of ecosystem condition change on the capacity of an ecosystem can be identified. This will help to attain the ideal of capacity accounts being closely linked to ecosystem condition accounts (Hein et al., 2015; UNEP et al., 2017).

The water case study recognized the various water-related ESs provided by aquatic and terrestrial ecosystems and the atmosphere. As stated in the case study, water-related accounting should cover the entire hydrological cycle and the various forms (water, snow, and ice) and sources of water since they all provide relevant services for the economy, that is, environment-economy interactions. Moreover, the accounts could also be used to study the interactions and dependencies among the various ecosystems to answer questions about how using a particular ES may affect the ability of other ecosystems to provide particular services.

An essential question regarding the compatibility of ecosystem accounting with SNA is whether various ESs are identified in frameworks, such as CICES and the Final Ecosystem Goods and Services Classification System (FEGS-CS), and how explicitly they are defined. The Finnish ES indicators were compiled using the current version of CICES (4.3), in which precipitation (rainfall) is categorized as surface water for non-drinking purposes. In the FEGS-CS documentation (Bordt, 2016), precipitation and its various uses (beneficiaries) within the economy are explicitly expressed. As the forest sector (managed forest) is highly dependent on precipitation and is the major contributor to the Finnish economy, considering FEGS-CS in the future development of Finnish ES indicators might increase the accuracy of the accounts and their relevance in decision making. This study indicates that CICES classification (V 4.3) as such would not be explicit enough for the SNA, which poses a risk that the outcomes from the application of CICES classification do not meet the needs of environmental-economic accounts. If this is the case, integration of ESs into the SNA may prove problematic. Hence, we call for closer collaboration between ecologists working with ES classification and SNA experts to guarantee that the documentation produced supports the integration of ESs into the present structures of economic accounting.

The output from ecosystem accounts can be used as input to an integrated account that unifies ecosystem accounting data with standard national account data. For instance, the results of ecosystem monetary asset accounts can be incorporated into a balance sheet. Another example is that the results of ES supply and use accounts can be used as inputs to extended supply and use tables or input-output tables, and they can further be used in input-output or computable general equilibrium models to support decision making (UNEP et al., 2017). In economic studies, the outcomes from such models traditionally reveal the interactions among various sectors, as well as the supply and use of intermediary and final products. Populating these various tables with ecosystem accounting data can help acknowledge the relations between ESs and sectors currently present in the SNA. The integration framework (Fig. 1) implies the importance of integrating the two systems for decision-making. Changes in structure and function indicators affect the extent, condition and capacity accounts; ES supply and use accounts reflect human activities. By comparing these accounting data across several years or by applying the account data to an input-output or computable general equilibrium model, it is possible to analyze the impacts of economic activities and specific policies on ecosystems.

5. Conclusions

Halting the alarming deterioration of the environment and enhancing the integration of environmental and socio-economic indicators are both defined as motivations in the EU's Biodiversity Strategy and the 7th Environment Action Programme. The practical measures of the MAES Working group and KIP-INCA project aim at integrating an environmental perspective into national accounting systems. This paper serves as a pilot to test how data from Finnish ES indicators can be used for ecosystem accounting. The two case studies show that although the ES indicators were not originally designed from an accounting perspective, they could be used in compiling ecosystem accounts following the SEEA-EEA statistical framework. The pilot also noted data gaps and mismatches in key definitions and revealed several avenues for future research.

Acknowledgements

Satu Turtiainen (Finnish Environment Institute) and Kaskas Media are acknowledged for their input on Fig. 2. Lai acknowledges funding from project MARmaED (The MARmaED project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675997. The results of this article reflect only the author's view, and the Commission is not responsible for any use that may be made of the information it contains). Oinonen and Salminen acknowledge the project 'Socio-ekonomisk nytta av arktiska ytvatten i Norden' funded by the Nordic Council of Ministers (project number 15228). Jäppinen, Mononen and Vihervaara acknowledge the funds received from the Finnish Ministry of the Environment to the MAES for Finland project, the Natural Capital background paper (Jäppinen and Heliölä, 2016) and the Fin-INCA project. We also acknowledge the Eurostat Grant (2017).

Appendix A

See Fig. A1 and Tables A1–A4.

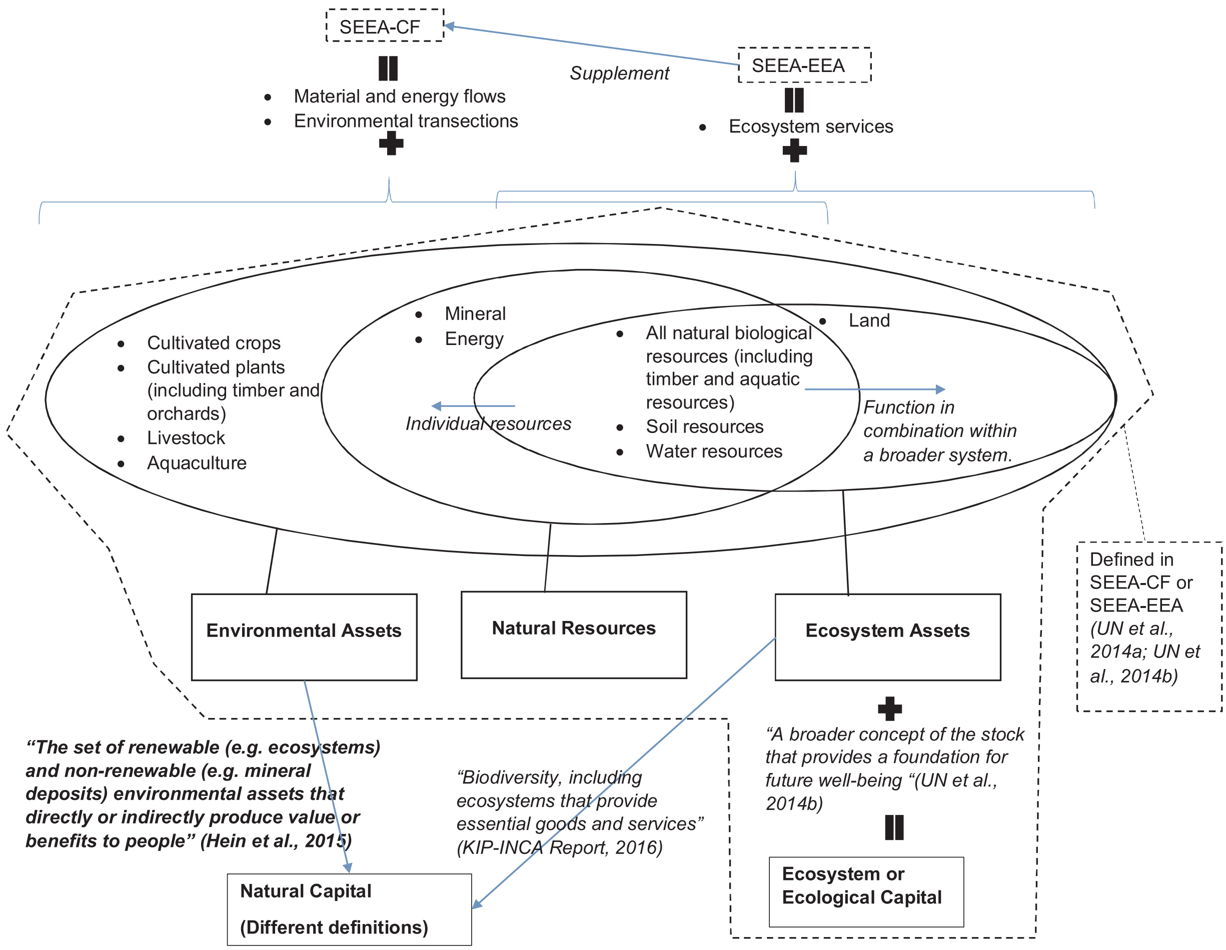

Fig. A1. The scope of SEEA-CF, SEEA-EEA, and different terms related to environmental assets.
SEEA-CF and SEEA-EEA cover the accounting for environmental assets and flows related to environment. The definitions of "environmental asset" and its subcategories can be found in Table A1. "Assets" and "capital" are often used interchangeably under the accounting framework (UN et al., 2014b), but the latter has a broader definition that emphasizes the values or benefits to humans. Natural capital was not defined in SEEA-CF or SEEA-EEA but has multiple definitions in the literature, which led to inconsistencies in different ecosystem accounting studies.

Table A1
Scope of SEEA-CF and SEEA-EEA, and the definitions of different environmental assets.

SEEA-CF	Three main areas of measurement: "*(1) the physical flows of materials and energy within the economy and between the economy and the environment; (2) the stocks of environmental assets and changes in these stocks; and (3) economic activity and transactions related to the environment*". (UN et al., 2014a, sec 2.6) In SEEA-CF, "the perspective for measurement purposes is on 'individual' environmental assets". (UN et al., 2014b, sec 1.19)
SEEA-EEA	The approach that "*assesses how different individual environmental assets interact as part of natural processes within a spatial area*". (UN et al. (2014b, sec 1.20)
Environmental assets	"*Naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity*". (UN et al., 2014a, sec 2.17)
Natural resources	"*All natural biological resources (including timber and aquatic resources), mineral and energy resources, soil resources, and water resources*". (UN et al., 2014a, sec 5.18)
Ecosystem assets	"*Environmental assets as viewed from a systems perspective*" (UN et al., 2014b, sec 1.20). "*Spatial areas comprising a combination of biotic and abiotic components and other elements which function together.*" (UN et al., 2014b, sec 2.31, 4.1)

Table A2
Annual ES use of groundwater, surface water, and cooling water abstraction and the rate of mains water use in 26 aggregated sectors in the Finnish economy in 2010.

NACE code	Sector description	Water abstraction[a] (m^3/year)				Resource rent of water abstraction from groundwater and surface water (million EUR)[d,e]
		Groundwater	Surface water	Cooling water[b]	Mains water[c]	
01	Agriculture	26 358 950	7 357 420	0	16 693 291	6.27
02	Forestry	0	0	0	21 282	0
07-09	Mining and quarrying	4 912 349	14 859 769	0	408 607	3.68
10–11	Food industry	5 514 456	2 603 617	10 751 291	16 130 734	1.51
13–15	Manufacture of textiles and wearing apparel	156 553	1 927 143	0	1 277 526	0.39
16	Wood product industry	456 432	6 631 299	0	413 393	1.32
17–18	Paper and pulp industry	782 611	481 746 616	595 607 604	968 656	89.70
19	Manufacture of refined petroleum products	454	7 483 000	689 867 000	1 151 377	1.39
20–22	Chemical industry	2 245 756	14 298 828	937 249 850	5 358 089	3.08
23	Manufacture of mineral products	746 034	673 787	2 201 177	1 478 424	0.26
24	Manufacture of basic metals	188 616	13 162 225	242 697 174	1 176 618	2.48
25; 28–30; 33	Manufacture of machinery and equipment	17 646	463 070	12 859 489	6 116 852	0.09
26-27	Electric industry	0	65 142	707 679	1 440 951	0.01
31–32	Industries n.e.c.	0	0	0	349 376	0
35	Energy production	0	7 190 772	5 646 688 323	2 287 823	1.34
36–38	Water supply, sanitation and waste management	233 740 000	169 260 000	0	64 915 197	74.91
41–43	Construction	0	0	0	936 012	0
45–47	Trade	0	0	0	6 543 867	0
49–53	Transportation and storage	0	0	16 340	2 006 236	0
55–56	Accommodation and food service activities	0	0	0	16 183 080	0
58–62	Information and communication	0	5 954 119	0	1 209 119	1.11
64–66; 70–81	Business services	0	331 743	306 108	3 141 727	0.06
68	Real estate activities	24 524 697	0	0	220 722 516	4.56
84	Public administration	183 751	0	0	5 071 135	0.03
85–88	Education, health and social services	210	0	0	15 110 435	0
90–96	Other services	1 795 529	8 304 428	0	12 360 142	1.88
	Total	**301 624 043**	**742 312 978**	**8 138 952 035**	**403 472 465**	**194.05**

[a] Reference:Salminen et al. (2017).
[b] Approximately 80% of the cooling water is brackish water, 20% fresh surface water and < 0.1% groundwater (unpublished results from Salminen et al., 2017).
[c] Mains water presents the allocation of the groundwater and surface water abstracted by the water supply sector (NACE 36) to manufacture drinking water to all sectors within the economy.
[d] Cooling water is not included.
[e] The calculation of resource rent can be found in Section 3.1.3.1.

Table A3
SSB of herring, sprat, and cod in Baltic Sea and Finnish share in 2012.

	Herring	Sprat	Cod
Total SSB in Baltic Sea (thousand tons)	1 520–2 054	863	170
Finnish catch share	56.7 %	3.8 %	2.4 %
SSB for Finnish accounts[a] (thousand tons)	863–1 165	33	4
Population in ICES subdivision (SD)	• SD 25–29 + 32 (excluding SD 28.1)[b] • SD 30[c] • SD 31	SD 22–32	• SD 25–32 (Eastern Baltic Sea)[d] • 22–24 (Western Baltic Sea)
References	(ICES, 2015a, b)	(ICES, 2015a)	(ICES, 2013, 2015a)

[a] SSB for Finnish accounts = Total SSB in Baltic Sea*Finnish catch share.
[b] SD 28.1 was not included as Finland does not have a catch share from this area.
[c] The estimated population in the Bothnian Sea (SD 30) in the ICES report (ICES, 2015a) and that in the ICES online database (ICES, 2015b) are different, probably due to model adjustment in the report. This results in the range of herring SSB values in the table.
[d] ICES (2015a) did not provide the SSB of cod in SD 25–32 for 2012, and thus we used the value from ICES (2013).

Table A4
Expected ES flows of Finnish fish provisioning ecosystem services.

	Physical term of expected ES flows (Unit: ton)				Monetary term of expected ES flows (Unit: EUR)	
year	Cod	Herring	Sprat	Total	Resource rent of future expected ES flows (considering inflation rate, without discounting)	NPV of expected ES flows (value of the asset)
2013	1 329	116 386	14 540	132 254	3 784 594	90 761 845
2014	1 241	115 599	16 017	132 856	3 885 459	
2015	1 348	111 263	16 736	129 347	3 866 042	
2016	1 345	107 493	17 312	126 149	3 853 422	
2017	1 288	105 671	17 857	124 816	3 896 585	
2018	1 268	104 952	18 284	124 504	3 972 346	
2019	1 271	104 505	18 617	124 394	4 056 151	
2020	1 258	104 499	18 829	124 585	4 151 756	
2021	1 235	104 057	18 998	124 291	4 233 067	
2022	1 224	104 003	19 130	124 357	4 328 503	
2023	1 216	103 981	19 228	124 425	4 426 135	
2024	1 203	104 049	19 310	124 562	4 528 487	
2025	1 190	104 193	19 382	124 765	4 635 663	
2026	1 180	104 377	19 443	125 000	4 746 559	
2027	1 170	104 584	19 497	125 251	4 860 740	
2028	1 160	104 814	19 546	125 520	4 978 346	
2029	1 150	105 058	19 592	125 800	5 099 240	
2030	1 141	105 315	19 636	126 091	5 223 470	
2031	1 132	105 576	19 676	126 384	5 350 797	
2032	1 123	105 840	19 715	126 679	5 481 278	
2033	1 115	106 106	19 753	126 974	5 614 886	
2034	1 107	106 369	19 788	127 265	5 751 583	
2035	1 100	106 630	19 823	127 552	5 891 380	
2036	1 092	106 886	19 856	127 834	6 034 307	
2037	1 085	107 138	19 888	128 111	6 180 391	

References

ABS, 2012. Completing the Picture - Environmental Accounting in Practice. Australian Bureau of Statistics (ABS) ABS catalogue number 4628.0.55.001.

ABS, 2015. Information Paper: An Experimental Ecosystem Account for the Great Barrier Reef Region. Australian Bureau of Statistics (ABS) ABS catalogue number 4680.0.55.001.

Ahtiainen, H., Öhman, M.C., 2013. The Baltic sea and the valuation of marine and coastal ecosystem services. In: Regional Workshop on the Valuation of Marine and Coastal Ecosystem Services in the Baltic Sea. 7–8 November, Stockholm.

Anna, Z., 2017. Indonesian shrimp resource accounting for sustainable stock management. Biodiversitas 18 (1), 248–256.

Artell, J., 2013. Vedenlaadun vaikutus kesämökkitonttien hintoihin. Vesitalous 1/2013. 27-29 pp.

Autio, N., Piirainen, A., Salomaa, E., Vahvelainen, S., 2013. Ympäristötilinpito kansantalouden tilinpidon täydentäjänä. Kansantaloudellinen aikakauskirja 109 (3), 331–350.

Bartelmus, P., 2009. The cost of natural capital consumption: accounting for a sustainable world economy. Ecol. Econ. 68 (6), 1850–1857. http://dx.doi.org/10.1016/j.ecolecon.2008.12.011.

Bartelmus, P., Stahmer, C., Tongeren, Jv., 1991. Integrated environmental and economic accounting: framework for a SNA satellite system. Rev. Income Wealth 37 (2), 111–148. http://dx.doi.org/10.1111/j.1475-4991.1991.tb00350.x.

Biodiversity.fi, 2014. Finnish Environment Institute (SYKE), Finnish Game and Fisheries Research Institute, Finnish Museum of Natural History, Finnish Forest Research Institute (Metla), BirdLife Finland, South Karelia Allergy and Environment Institute, Metsähallitus Natural Heritage Services, Retrieved 12/09/2017, from https://www.biodiversity.fi/en/home.

Bordt, M., 2016. Concordance between FEGS-CS and CICES V4.3 (DRAFT – research in progress). Expert Group Meeting - Towards a Standard International Classification on Ecosystem Services, 20-21 June 2016. New York.

Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecol. Econ. 63 (2), 616–626. http://dx.doi.org/10.1016/j.ecolecon.2007.01.002.

Britschgi, R., Antikainen, M., Ekholm-Peltonen, M., Hyvärinen, V., Nylander, E., Siiro, P., Suomela, T., 2009. Pohjavesialueiden kartoitus ja luokitus [Mapping and Classification of Groundwater Areas]. Finnish Environment Institute (SYKE).

Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Indic. 21, 17–29. http://dx.doi.org/10.1016/j.ecolind.2011.06.019.

Claus, S., Hauwere, N.D., Vanhoorne, B., Dias, F.S., García, P.O., Hernandez, F., Mees, J., (Flanders Marine Institute), 2016. MarineRegions.org. Retrieved 20/03/2017, from http://www.marineregions.org/eezdetails.php?mrgid=5676.

Collie, J.S., Gislason, H., 2001. Biological reference points for fish stocks in a multispecies context. Can. J. Fish. Aquat. Sci. 58 (11), 2167–2176. http://dx.doi.org/10.1139/cjfas-58-11-2167.

Eigenraam, M., McCormick, F., Contreras, Z., 2016. Marine and Coastal Ecosystem Accounting: Port Phillip Bay: Report to the Commissioner for Environmental Sustainability. The State of Victoria Department of Environment, Land, Water and Planning.

European Commission, 2015. Scientific, Technical and Economic Committee for Fisheries (STECF) – The 2015 Annual Economic Report on the EU Fishing Fleet (STECF-15-07). JRC Scientific and Technical Reports. Publications Office of the European Union, Luxembourg 434 pp.

European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations, World Bank, 2009. System of National Accounts 2008. United Nations, New York, 662 pp.. .

EUROSTAT, 2008. NACE Rev. 2: Statistical Classification of Economic Activities in the European Community, Luxembourg.

Eurostat, 2017. HICP (2015 = 100) - Annual Data (average index and rate of change). Retrieved 2017/03/20, from. http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00027&plugin=1.

Gislason, H., 1999. Single and multispecies reference points for Baltic fish stocks. ICES J. Mar. Sci. 56 (5), 571–583. http://dx.doi.org/10.1006/jmsc.1999.0492.

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being. In: In: Raffaelli, D.G., Frid, C.L.J. (Eds.), Ecosystem Ecology: A New Synthesis, vol. 9. Cambridge University Press, Cambridge, pp. 110–139.

Hein, L., Bagstad, K., Edens, B., Obst, C., de Jong, R., Lesschen, J.P., 2016. Defining ecosystem assets for natural capital accounting. PLoS One 11 (11), e0164460. http://dx.doi.org/10.1371/journal.pone.0164460.

Hein, L., Obst, C., Edens, B., Remme, R.P., 2015. Progress and challenges in the development of ecosystem accounting as a tool to analyse ecosystem capital. Curr. Opin. Environ. Sustain. 14, 86–92. http://dx.doi.org/10.1016/j.cosust.2015.04.002.

Hoffrén, J., Salomaa, E., 2014. Ympäristötilinpidon kuvausalue laajenee (in Finnish) Kansantaloudellinen aikakauskirja 110. pp. 406–410.

ICES, 2012. Report of the Baltic Fisheries Assessment Working Group 2012 (WGBFAS). ICES CM 2012/ACOM:10. Copenhagen, Denmark, 869 pp.. .

ICES, 2013. Report of the ICES Advisory Committee 2013. ICES Advice, 2013. Book 8. 167 pp.. .

ICES, 2015a. Report of the Baltic Fisheries Assessment Working Group (WGBFAS). ICES CM 2015/ACOM:10. Copenhagen, Denmark., 826 pp.. .

ICES, 2015b. Stock Assessment Graphs: Herring in Subdivision 30 (Bothnian Sea). Retrieved 2017/3/22, from. http://standardgraphs.ices.dk/ViewCharts.aspx?key=6825.

Jäppinen, J.-P., Heliölä, J., 2016. Suomen luontopääoman tilinpitoa koskevan kansallisen kehittämistyön sisältö ja vaatimukset [Defining the Content and Demands for Natural Capital Accounting in Finland]. Project 7000T-YVL003. Finnish Environment Institute (SYKE), Natural Environment Centre. Esiselvitys ympäristöministeriölle, Helsinki.

Kettunen, I., Mäkelä, A., Heinonen, P., 2008. Sampling for Water Quality and Biota (In Finnish). Finnish Environment Institute (SYKE).

Khan, J., Din, F., Office for National Statistics, 2015. UK Natural Capital – Freshwater Ecosystem Assets and Services Accounts.

KIP-INCA Report, 2016. Report on Phase 1 of the Knowledge Innovation Project on an Integrated System of Natural Capital and Ecosystem Services Accounting in the EU (KIP-INCA Phase 1 Report). European Commission and European Environment Agency 106 pp.
Kløve, B., Allan, A., Bertrand, G., Druzynska, E., Ertürk, A., Goldscheider, N., Henry, S., Karakaya, N., Karjalainen, T.P., Koundouri, P., Kupfersberger, H., Kværner, J., Lundberg, A., Muotka, T., Preda, E., Pulido-Velazquez, M., Schipper, P., 2011. Groundwater dependent ecosystems. Part II. Ecosystem services and management in Europe under risk of climate change and land use intensification. Environ. Sci. Policy 14 (7), 782–793. http://dx.doi.org/10.1016/j.envsci.2011.04.005.
Koster, F., Mollmann, C., Hinrichsen, H., Wieland, K., Tomkiewicz, J., Kraus, G., Voss, R., Makarchouk, A., Mackenzie, B., Stjohn, M., 2005. Baltic cod recruitment – the impact of climate variability on key processes. ICES J. Mar. Sci. 62 (7), 1408–1425. http://dx.doi.org/10.1016/j.icesjms.2005.05.004.
La Notte, A., Maes, J., Dalmazzone, S., Crossman, N.D., Grizzetti, B., Bidoglio, G., 2017a. Physical and monetary ecosystem service accounts for Europe: a case study for in-stream nitrogen retention. Ecosyst. Serv. 23, 18–29. http://dx.doi.org/10.1016/j.ecoser.2016.11.002.
La Notte, A., Vallecillo, S., Polce, C., Zulian, G., Maes, J., 2017b. I Implementing an EU System of Accounting for Ecosystems and Their Services. Initial Proposals for the Implementation of Ecosystem Services Accounts. EUR 28681 EN; Publications Office of the European Union, Luxembourg. http://dx.doi.org/10.2760/214137.
Lampi, P., Hakulinen, T., Luostarinen, T., Pukkala, E., Teppo, L., 1992. Cancer incidence following chlorophenol exposure in a community in southern Finland. Arch. Environ. Health 47 (3), 167–175. http://dx.doi.org/10.1080/00039896.1992.9938346.
Launiainen, S., Futter, M.N., Ellison, D., Clarke, N., Finer, L., Hogbom, L., Lauren, A., Ring, E., 2014. Is the water footprint an appropriate tool for forestry and forest products: the Fennoscandian case. Ambio 43 (2), 244–256. http://dx.doi.org/10.1007/s13280-013-0380-z.
LUKE, 2014. LUKE Statistics Database: Catch by Recreational Fishermen by Fishing Area (1 000 Kg, Crayfish 1 000 Indiv). Retrieved 20/09/2017, from. http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE_06%20Kala%20ja%20riista_02%20Rakenne%20ja%20tuotanto_06%20Vapaa-ajankalastus/3_Vapaa-ajankalastuksen_saalis_alue.px/?rxid=dc711a9e-de6d-454b-82c2-74ff79a3a5e0.
LUKE, 2015. LUKE Statistics Database: Value of Catches in Commercial Marine Fishery (1000 e). LUKE Statistics database Retrieved 2017/2/2, from. http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE_06%20Kala%20ja%20riista_02%20Rakenne%20ja%20tuotanto_02%20Kaupallinen%20kalastus%20merella/5_meri_saalis_arvo.px/?rxid=dc711a9e-de6d-454b-82c2-74ff79a3a5e0.
LUKE, 2016. LUKE Statistics Database: Catches in Commercial Marine Fishery (1000 Kg). Retrieved 2017/2/26, from. http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE_06%20Kala%20ja%20riista_02%20Rakenne%20ja%20tuotanto_02%20Kaupallinen%20kalastus%20merella/4_meri_saalis.px/?rxid=dc711a9e-de6d-454b-82c2-74ff79a3a5e0.
LUKE, 2017. LUKE Statistics Database: Catches in Commercial Marine Fishery (1000 Kg). Retrieved 20/03/2017, from. http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE_06%20Kala%20ja%20riista_02%20Rakenne%20ja%20tuotanto_02%20Kaupallinen%20kalastus%20merella/4_meri_saalis.px/?rxid=dc711a9e-de6d-454b-82c2-74ff79a3a5e0.
Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M.L., Barredo, J.I., Grizzetti, B., Cardoso, A., Somma, F., Petersen, J.-E., Meiner, A., Gelabert, E.R., Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Piroddi, C., Egoh, B., Degeorges, P., Fiorina, C., Santos-Martín, F., Naruševičius, V., Verboven, J., Pereira, H.M., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., San-Miguel-Ayanz, J., Pérez-Soba, M., Grêt-Regamey, A., Lillebø, A.I., Malak, D.A., Condé, S., Moen, J., Czúcz, B., Drakou, E.G., Zulian, G., Lavalle, C., 2016. An indicator framework for assessing ecosystem services in support of the EU biodiversity strategy to 2020. Ecosyst. Serv. 17, 14–23. http://dx.doi.org/10.1016/j.ecoser.2015.10.023.
Magnussen, K., Kettunen, M., et al., 2013. TEEB nordic case: Marine ecosystem services in the Barents sea and Lofoten islands, a scoping assessment. In: Kettunen (Ed.), Socio-economic Importance of Ecosystem Services in the Nordic Countries - Scoping Assessment in the Context of The Economics of Ecosystems and Biodiversity (TEEB). Nordic Council of Ministers, Copenhagen.
Metsähallitus, 2017. Kansallispuistojen, valtion retkeilyalueiden ja muiden virkistyskäytöllisesti merkittävimpien metsähallituksen hallinnoimien suojelualueiden ja retkeilykohteiden käyntimäärät vuonna 2016.
Molarius, R., Poussa, L., 2001. Merkittävät pohjaveden pilaantumistapaukset Suomessa 1976-2000 [The Most Significant Ground Water Contamination Cases in Finland in 1976-2000]. Suomen ympäristö. Tampere. Pirkanmaan ympäristökeskus. .
Mononen, L., Auvinen, A.P., Ahokumpu, A.L., Rönkä, M., Aarras, N., Tolvanen, H., Kamppinen, M., Viirret, E., Kumpula, T., Vihervaara, P., 2016. National ecosystem service indicators: measures of social–ecological sustainability. Ecol. Indic. 61 (Pt. 1), 27–37. http://dx.doi.org/10.1016/j.ecolind.2015.03.041.
National Land Survey, 2017. Maanmittauslaitoksen vuositilastoja 2016. Retrieved 01/09/2017, from. Svt Suomen Virallinen Tilasto. http://www.maanmittauslaitos.fi/tietoa-maanmittauslaitoksesta/organisaatio/tilastot.
Nieminen, E., Kronbak, L.G., Lindroos, M., 2016. International agreements in the multi-species Baltic sea fisheries. Environ. Resour. Econ. 65 (1), 109–134. http://dx.doi.org/10.1007/s10640-015-9933-x.
Nieminen, E., Lindroos, M., Heikinheimo, O., 2012. Optimal bioeconomic multispecies fisheries management: a Baltic sea case study. Mar. Resour. Econ. 27 (2), 115–136. http://dx.doi.org/10.5950/0738-1360-27.2.115.
Nieminen, M., 2009. Free-time Residence Barometer (In Finnish). Statistics Finland.
Nordhaus, W.D., 2006. Principles of national accounting for nonmarket accounts. In: Jorgenson, D.W., Landefeld, J., Nordhaus, W.D. (Eds.), A New Architecture for the US National Accounts. University of Chicago Press pp. 143–160.
Obst, C., Hein, L., Edens, B., 2016. National accounting and the valuation of ecosystem assets and their services. Environ. Resour. Econ. 64 (1), 1–23. http://dx.doi.org/10.1007/s10640-015-9921-1.
Office for National Statistic, 2016. UK Environmental Accounts: 2016. Retrieved 01/12/2016, from. https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/ukenvironmentalaccounts/2017.
Ottersen, G., Hjermann, D.A.G.Ø., Stenseth, N.C., 2006. Changes in spawning stock structure strengthen the link between climate and recruitment in a heavily fished cod (Gadus morhua) stock. Fish. Oceanogr. 15 (3), 230–243. http://dx.doi.org/10.1111/j.1365-2419.2006.00404.x.
Piet, G.J., van Overzee, H.M.J., Miller, D.C.M., Gelabert, E.R., 2017. Indicators of the 'wild seafood' provisioning ecosystem service based on the surplus production of commercial fish stocks. Ecol. Indic. 72, 194–202. http://dx.doi.org/10.1016/j.ecolind.2016.08.003.
Pope, K.L., Pegg, M.A., Cole, N.W., Siddons, S.F., Fedele, A.D., Harmon, B.S., Ruskamp, R.L., Turner, D.R., Uerling, C.C., 2016. Fishing for ecosystem services. J. Environ. Manage. 183 (Pt. 2), 408–417. http://dx.doi.org/10.1016/j.jenvman.2016.04.024.
Remme, R.P., Edens, B., Schröter, M., Hein, L., 2015. Monetary accounting of ecosystem services: a test case for Limburg province, the Netherlands. Ecol. Econ. 112, 116–128. http://dx.doi.org/10.1016/j.ecolecon.2015.02.015.
Remme, R.P., Schröter, M., Hein, L., 2014. Developing spatial biophysical accounting for multiple ecosystem services. Ecosyst. Serv. 10, 6–18. http://dx.doi.org/10.1016/j.ecoser.2014.07.006.
Repetto, R., 1992. Accounting for environmental assets. Sci. Am. 266 (6), 94–101.
Salminen, J., Tikkanen, S., Koskiaho, J., Kirkkala, T., Mäenpää, I., 2017. Kohti vesiviisasta kiertotaloutta [Towards Water-smart Circular Economy]. Reports of the Finnish Environment Institute 16/ 2017. Finnish Environment Institute (SYKE), Helsinki.
Säylä, J., Vilpas, R., 2012. Urban Wastewater Treatment 2010 (In Finnish). Reports of the Finnish Environment Institute 21/2012. Finnish Environment Institute (SYKE), Helsinki.
Schröter, M., Barton, D.N., Remme, R.P., Hein, L., 2014. Accounting for capacity and flow of ecosystem services: a conceptual model and a case study for Telemark, Norway. Ecol. Indic. 36, 539–551. http://dx.doi.org/10.1016/j.ecolind.2013.09.018.
SLU, 2010. Kansallinen liikuntatutkimus 2009-2010. Suomen Liikunta ja Urheilu (SLU).
Statistics Finland, 2016. Sähkön ja lämmön tuotanto 2015. Official Statistics of Finland.
Statistics Finland, 2017a. Environment and Natural Resources. Retrieved 01/07, from. http://tilastokeskus.fi/til/ymp_en.html.
Statistics Finland, 2017b. Statistics Finland's PX-Web Databases: Production and Generation of Income Accounts 1975-2016. Retrieved 29/09/2017, from. http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin_kan_vtp/070_vtp_tau_071.px/?rxid=81ee2b0c-82d1-44ce-9a07-e5734d97b472.
Statistics Finland, 2017c. Statistics Finland's PX-Web Databases: Use Table at Basic Prices 2010-2014 (TOL2008/CPA2008) ESA 2010. Retrieved 15/3/2017, from. http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin_kan_pt/120_pt_tau_102.px/?rxid=81ee2b0c-82d1-44ce-9a07-e5734db472.
Statistics South Africa, 2012. Fishery Accounts for South Africa: 1990-2010. Statistics South Africa.
SYKE, 2016. (5/10/2016). Pohjavesien määrällinen ja kemiallinen tila. Retrieved 15/09, from. http://www.ymparisto.fi/fi-FI/Vesi/Pohjavesien_tila.
SYKE, 2017. (14/7/2017). Pintavesien ekologinen ja kemiallinen tila. Retrieved 15/09/2017, from. http://www.ymparisto.fi/fi-FI/Vesi/Pintavesien_tila.
Tattari, S., Puustinen, M., Koskiaho, J., Röman, E., Riihimäki, J., 2015. Emissions to Surface Water Bodies from Different Industries and Reduction Opportunities (in Finnish). Reports of the Finnish Environment Institute 35/2015. Finnish Environment Institute (SYKE), Helsinki.
Tike, 2013. Agricultural Census (In Finnish and In Swedish). Information Centre of the Ministry of Agriculture and Forestry(Tike).
UK National Ecosystem Assessment, 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.
United Nations, 2012. SEEA-Water: System of Environmental-Economic Accounting for Water. Department of Economic and Social Affairs, Statistics Division, United Nations.
United Nations, European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development, The World Bank, 2014a. System of Environmental-Economic Accounting 2012—Central Framework. United Nations and European Union. New York, 378 pp.. .
United Nations, European Union, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, World Bank Group, 2014b. System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting. United Nations and European Union. New York, 198 pp.. .
United Nations Environment Programme, United Nations Statistics Division, Convention on Biological Diversity, 2017. SEEA Experimental Ecosystem Accounting:Technical Recommendations. Consultation Draft - V4.1: 6 March 2017. Project on Advancing Natural Capital Accounting Funded by NORAD.
Villamagna, A.M., Angermeier, P.L., Bennett, E.M., 2013. Capacity, pressure, demand, and flow: a conceptual framework for analyzing ecosystem service provision and delivery. Ecol. Complexity 15, 114–121. http://dx.doi.org/10.1016/j.ecocom.2013.

07.004.
Walters, C., Christensen, V., Martell, S., Kitchell, J., 2005. Possible ecosystem impacts of applying MSY policies from single-species assessment. ICES J. Mar. Sci. 62 (3), 558–568. http://dx.doi.org/10.1016/j.icesjms.2004.12.005.
WAVES, 2017. WAVES Annual Report 2017. The World Bank, Washington.
Weber, J.-L., 2014. Experimental Ecosystems Natural Capital Accounts Mauritius Case Study: Methodology and Preliminary Results. Indian Ocean Commission, pp. 2000–2010.
Wijesingha, J., 2016. Corine Land Cover (CLC) 2012, Version 18.5.1. Retrieved 12/09/2017, from. http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012.
Zacheus, O., 2008. Suurten yleisten uimarantojen: valvonta ja veden laatu. pp. 2003–2006.